ASSESSING THE CAUSES FOR THE RISE IN ABUNDANCE AND SEASONAL PRODUCTIVITY OF THE GREEN MIXOTROPHIC DINOFLAGELLATE *NOCTILUCA* IN THE ARABIAN SEA ECOSYSTEM

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Background

Over the past two decades, unprecedented changes in biological productivity have been observed in the northern Arabian Sea and the Sea of Oman. Anomalous increases in ocean color following the onset of the winter monsoon have been largely attributed to blooms of the green mixotrophic dinoflagellate, *Noctiluca scintillans*. Intensified winter *Noctiluca* productivity has been shown to significantly decrease phytoplankton biodiversity within the Arabian Sea ecosystem. However, the causes for the seasonal dinoflagellate blooms are not understood.

The recent rise in abundance and seasonal productivity of *Noctiluca scintillans* may be caused by anthropogenic climate perturbations and heightened regional hypoxia or by soluble iron inputs via atmospheric forcing of mineral dust. In addition, seasonal eddies may contribute to the development and dispersal of these *Noctiluca* blooms in the northern Arabian Sea.

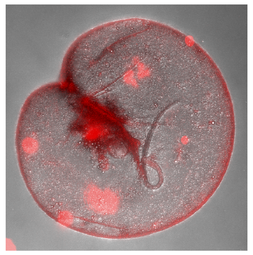

Figure 1: The heterotrophic form of *Noctiluca scintillans* (cell diameter ~350 µm)

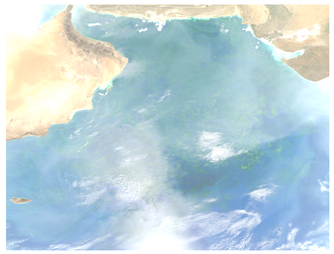

Figure 2: Winter blooms in the Arabian Sea under a dust storm (image courtesy of SAC IRS-P4 OCM)

Objectives

1. Determine the effects of low dissolved oxygen on the symbiont-enabled photoautotrophic growth of green *Noctiluca*
2. Examine the effects of seasonal dust deposition on green *Noctiluca* growth under a range of dissolved oxygen concentrations
3. Establish the ecological impacts of climate change in the Arabian Sea ecosystem

Study Area

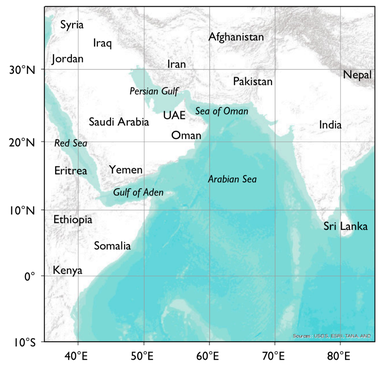

Figure 3: Recent rises in the abundance and productivity of the mixotrophic form of *Noctiluca* in the northern Arabian Sea and the Sea of Oman suggest potentially significant climate-driven changes to ecosystem function

Methodology

1. Laboratory incubation experiments under a range of dissolved oxygen concentrations
2. Aerosol and trace element analyses
3. NASA satellite observations

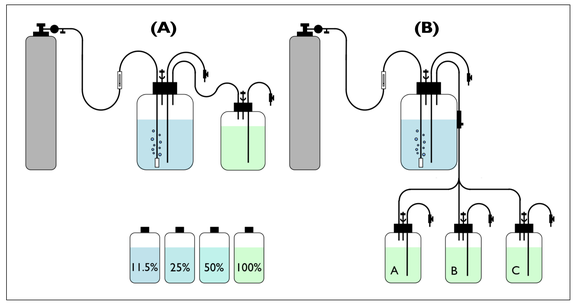

Figure 4: (A) Dilution-based grazing experiments using heterotrophic *Noctiluca* and the chlorophyte prey, *Dunaliella* sp. and (B) growth experiments using the diatom prey, *Thalassiosira weissflogii*

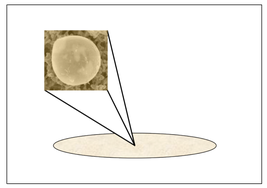

Figure 5: Aerosol leaching and digestion using a filter collected in the central Arabian Sea in February 2009 (http://www.nasa.gov/)

Trace element analyses methods include: (1) automated extraction using Nobias-chelate PA1 resin, (2) $Mg(OH)_2$ co-precipitation

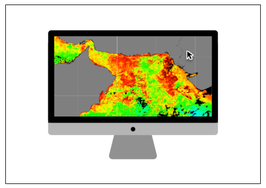

Figure 6: Comparisons of ocean color and sea surface height anomaly (SSHA) data in the Arabian Sea using MODIS Aqua chlorophyll *a* concentrations (8-day composite) and AVISO sea surface height anomalies (weekly, merged) (http://oceancolor.gsfc.nasa.gov/)

Results

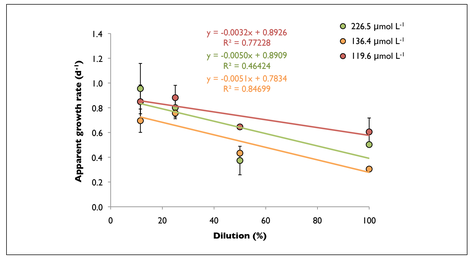

Figure 7: Linear regressions of apparent growth rate as a function of dilution percentage in the *Noctiluca* grazing experiments

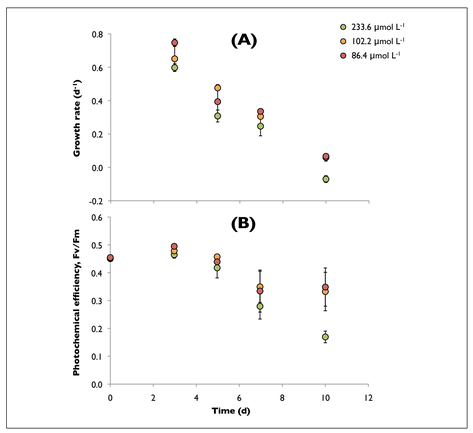

Figure 8: (A) Growth rate and (B) photochemical efficiency as a function of incubation time in the *T. weissflogii* growth experiments

Aerosol species	Concentration (ng filter^{-1})	Percent solubility (%)
Al	3548.5	15.5
Fe	8899.6	7.4
V	26.0	36.4

Table 1: Total aerosol concentration and solubility of several species from the sample filter

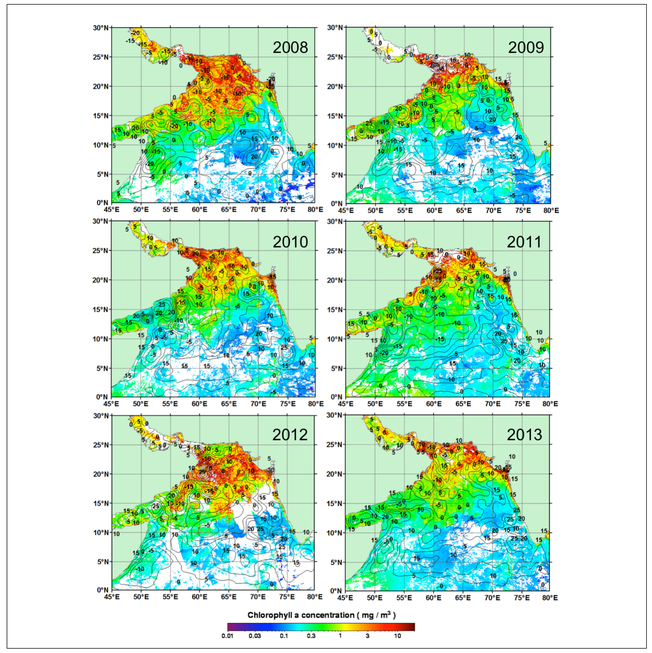

Figure 9: Spatial patterns of chlorophyll *a* concentration in mid-February from 2008 to 2013, overlaid with contours of SSHA

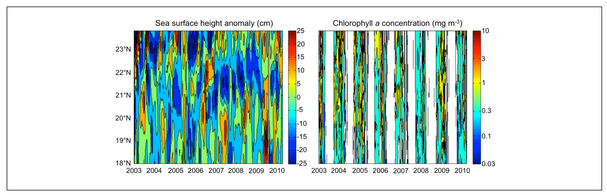

Figure 10: Hovmöller diagrams of SSHA and chlorophyll *a* concentration along a coastal transect from 18-24°N at 61°E

Impact and Relevance

This interdisciplinary assessment integrates satellite observations, controlled laboratory experiments, and field assessments to improve the current understanding of the following:

- the coupled biological, chemical, and physical causes for the unprecedented proliferation of *Noctiluca scintillans* in the Arabian Sea
- the broader implications of climate variability for biodiversity in the Arabian Sea, as well as in other sensitive marine ecosystems vulnerable to global change

Conclusions

- *Noctiluca* may have a competitive advantage for grazing under low dissolved oxygen concentrations
- Prey species *T. weissflogii* may also thrive under low dissolved oxygen concentrations
- Anthropogenic iron enrichment, as observed in the central Arabian Sea during the winter bloom in February 2009, may have implications for seasonal productivity
- Trace elements (e.g., Fe, Th, and Pb) in seawater samples can be analyzed using either of two analytical techniques prior to ICP-MS analysis
- Mesoscale eddy activity, along with reduced dissolved oxygen concentrations and mineral dust inputs during the winter monsoon, may be augmenting the spatial and temporal scales of seasonal *Noctiluca* blooms

Future Work

- Collect and culture mixotrophic *Noctiluca*
- Conduct growth experiments with mixotrophic *Noctiluca* and/or *Cochlodinium polykrikoides* using aerosol leachate additions under a range of dissolved oxygen concentration
- Analyze ocean color, SSHA, aerosol optical thickness, and sea surface temperature data during the winter bloom of 2014
- Complete two-dimensional, basin-wide cross-correlations and cross-spectral comparisons of filtered chlorophyll *a* concentration and SSHA data
- Use satellite data in conjunction with laboratory and field assessments to better predict climate-driven ecological consequences of green *Noctiluca* blooms in the Arabian Sea

References

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Acknowledgements

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